HAZARDOUS ICE ATLAS OF ARCTIC CANADA

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JANUARY 1983

Prepared for

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CONTENTS

ABSTRACT

An atlas of hazardous ice conditions for shipping in the Canadian Arctic has been prepared for Transport Canada, Canadian Coast Guard (Northern). The conditions presented represent monthly estimates of typical conditions for pressure ridges, multi-year ice and glacial ice throughout the Arctic. The estimates are based substantially on observed data where available, and on concensus projections to 'fill the gap'. The atlas is meant to be used to assess the general potential risk to Arctic shipping, not as data for navigation or other purposes.

INTRODUCTION

ARCTEC CANADA LIMITED, under the direction of TRANSPORT CANADA, Canadian Coast Guard Northern (CCGN), has carried out studies related to the update of the Canadian Arctic Shipping Pollution Prevention Regulations (CASPPR). Decisions concerning CASPPR require knowledge of the hazardous ice in the Arctic. The HAZARDOUS ICE ATLAS OF ARCTIC CANADA was developed to meet a specific objective of CCGN:

> "Recognizing a need for a decision on whether the distribution of hazardous ice in the Canadian Arctic is such that ships must be designed for colliding with it and recognizing the limitations of the available data on that ice, to produce as accurately as practical an estimate of that distribution in space and time in a form suitable for the decision."

THE HAZARDOUS ICE ATLAS OF ARCTIC CANADA represents a major revision to the ice data appendices of reference [1]. Ice, is of course, not intrinsically hazardous, but can be potentially hazardous to shipping. Three forms of ice represented in this Atlas are hazardous due to the fact that they can potentially induce very high forces and pressures on ships. These three forms are pressure ridges, multi-year ice and glacial ice (icebergs and associated bergy bits and growlers). As well 'special features' such as ice islands and icebergs outside the main iceberg zones are listed. While it is realized that other ice conditions such as thick first year ice and ice under pressure can cause damage to ships, it is pressure ridges, multi-year ice and glacial ice that represent the most important hazards to Arctic shipping.

INTERPRETATIONS OF ICE CONDITIONS

The conditions shown in the atlas are meant to represent the 'typical' year. For multi-year ice, 'typical' is taken to represent the mathematical median of all observed values (taken from Markham's Ice Atlas [2]). For the glacial ice and pressure ridge conditions, 'typical' is taken to represent the mathematical average of all observed values. For many zones and months, observations were not available and pragmatic estimates of 'typical' conditions were made in keeping with the objectives of the work. It must be stressed that the actual ice conditions will vary greatly from the predicted ice conditions. Often, the actual ice conditions will be more severe or less severe than the predictions. Therefore the atlas should not be casually compared with specific observations on specific years. It is hoped that as more data is obtained, a more detailed description of hazardous ice, including expected extreme values, will result.

PRESSURE RIDGES

Pressure ridge data was obtained from two sources, AES laser profilometry and United States "Bird's Eye" overflights. The laser data is an analogue signal representing the surface profile of ice along a straight line. Ridges result in peaks on the profile and are counted according to a predefined set of instructions concerning the size of the peak. The "Bird's Eye" data resulted from visual observations from an observation port in a slow flying (60 knots) aircraft. The observer counted ridges for one minute (passing by a line on the window), on the third, sixth and ninth minutes of a ten minute period. The raw data was multiplied by ten to give a frequency of ridges per thirty nautical miles. This data has been averaged to the number of ridges per kilometer for each zone and each month. The "Bird's Eye" data is generally higher frequency than the laser data due to the differences in recording technique. In this atlas "Bird's Eye" information has been used as the main indication of ridge frequency, with laser data and pragmatic estimations used to complete the picture.

MULTI-YEAR ICE

Multi-year ice conditions are based extensively on Markham's Ice Atlas [2]. Markham's work used fifteen years of data for virtually all of the Canadian Arctic and is based on digitized versions of (A.E.S.) composite ice charts. Original composites were not accessed, except as spot checks. The atlas provided data which was already statistically treated and presented as 'typical' (median) conditions.

Winter data is not available in such a summary format and at the time of data base development only one year of provision winter composite ice charts were available from A.E.S., for a year that was not necessarily considered typical. A number of researchers and experts familiar with navigation and ice conditions in the Arctic were consulted for their opinions and ideas about multi-year ice conditions through the winter, and their comments were incorporated into the mapped data base which resulted.

GLACIAL ICE

Glacial ice data (icebergs and bergy bits and growlers) has been taken exclusively from the International Ice Patrol Reports from 1948 to 1978, for flights north of 61°N. These data were listed on maps with a grid of 2° x 4°. Arithmetic means of the data in grid cells for months where more than one observation occurred were calculated. These were available for the months January, February, March, July, August, September, October. From this information, comments received by knowledgeable experts and the rational listed below, monthly estimates of population for each grid call were determined. Currents and general circulation, ice concentrations and production estimates were used to develop the rational. It must be noted that the minimum size of icebergs observed by the I.I.P. is assumed to be 100 meter waterline diameter. Of course, a great many bergs less than 100 meters surely exist and would present a hazard to shipping. Vandall [3] has suggested that there are 2.5 times more bergs smaller than 100 meters than larger, which due to altitude and weather were not reported by the I.I.P. This information must be kept in mind when using this atlas. The glacial ice data has been rounded to a partial order of magnitude to reflect their nature as general estimates.

RATIONALE FOR ESTIMATING POPULATIONS OF ICEBERGS

AUGUST	Close to 1949 census, but all in round numbers. High production in Greenland, high numbers along coast, some drifting across southern Baffin Bay - Davis Strait.
SEPTEMBER	Production decreases as freeze up starts - this causes slightly less transfer of bergs in North Baffin Bay.
OCTOBER	Production decreases further - bays begin to freeze, transfer of bergs along coast decreases, a bulge of bergs begins to move south.
NOVEMBER	Production is very low and coastal numbers down too. These are beginning to cease transfer and in some locations the numbers will remain the same until Spring. The bulge is in Davis Strait and numbers begin to drop in areas not frozen but which are receiving few new bergs.
DECEMBER	Production stabilizes - most coastal areas also stabilize - numbers decreasing in Baffin Bay where it is not frozen.
JANUARY	Main changes are to 'flush' remaining numbers to the south.
FEBRUARY	Similar to January but a slight increase in numbers in Davis Strait (based on the I.I.P. observations). These bergs likely to survive all the way from East Greenland due to cooler temperatures.
MARCH	Similar to February. East Greenland bergs move farther north before crossing.
APRIL	Similar to March. East Greenland bergs move farther north before crossing.
MAY	Production still the same as April but melting is releasing bergs from pack in south.
JUNE	Bergs are being released from the pack and moving into new areas, boosting numbers. Warmer water is melting bergs in the south, reducing some numbers there.
JULY	Production increasing at glaciers - melting pack releasing bergs. Numbers generally up every where, except in the south where melt occurs to many bergs.

SPECIAL FEATURES

Special features are by their very nature, rare and difficult to quantify. They have been included from Lindsay's Sea Ice Atlas 1977 [4] and are meant to represent conditions (ice islands and rare icebergs) that are reasonably possible but cannot be considered 'typical'. They have been included to alert the reader to these potential hazards that might otherwise be overlooked.

AKNOWLEDGEMENTS

The authors are indebted to a great many people for their comments and input during the development of this Atlas, including:

°W. Markham, Atmospheric Environment Service
°D. Mudry, Atmospheric Environment Service
°A. Beaton, Atmospheric Environment Service
°M. Luce, Canarctic Shipping Co., Ltd.
°P. Vandall, Energy, Mines and Resources
°B. Dixit, Melville Shipping Ltd.
°J. Miller, PetroCanada
°S. Hotzel, PetroCanada
°P. Noble, Arctec Canada Limited
°M. Perchanok, Arctec Canada Limited
°G. Comfort, Arctec Canada Limited

We believe that the consensus for which we strived has been substantially achieved.

Special thanks goes to R. Gardner for her stalwart dedication to quality during the many weeks of map preparation.

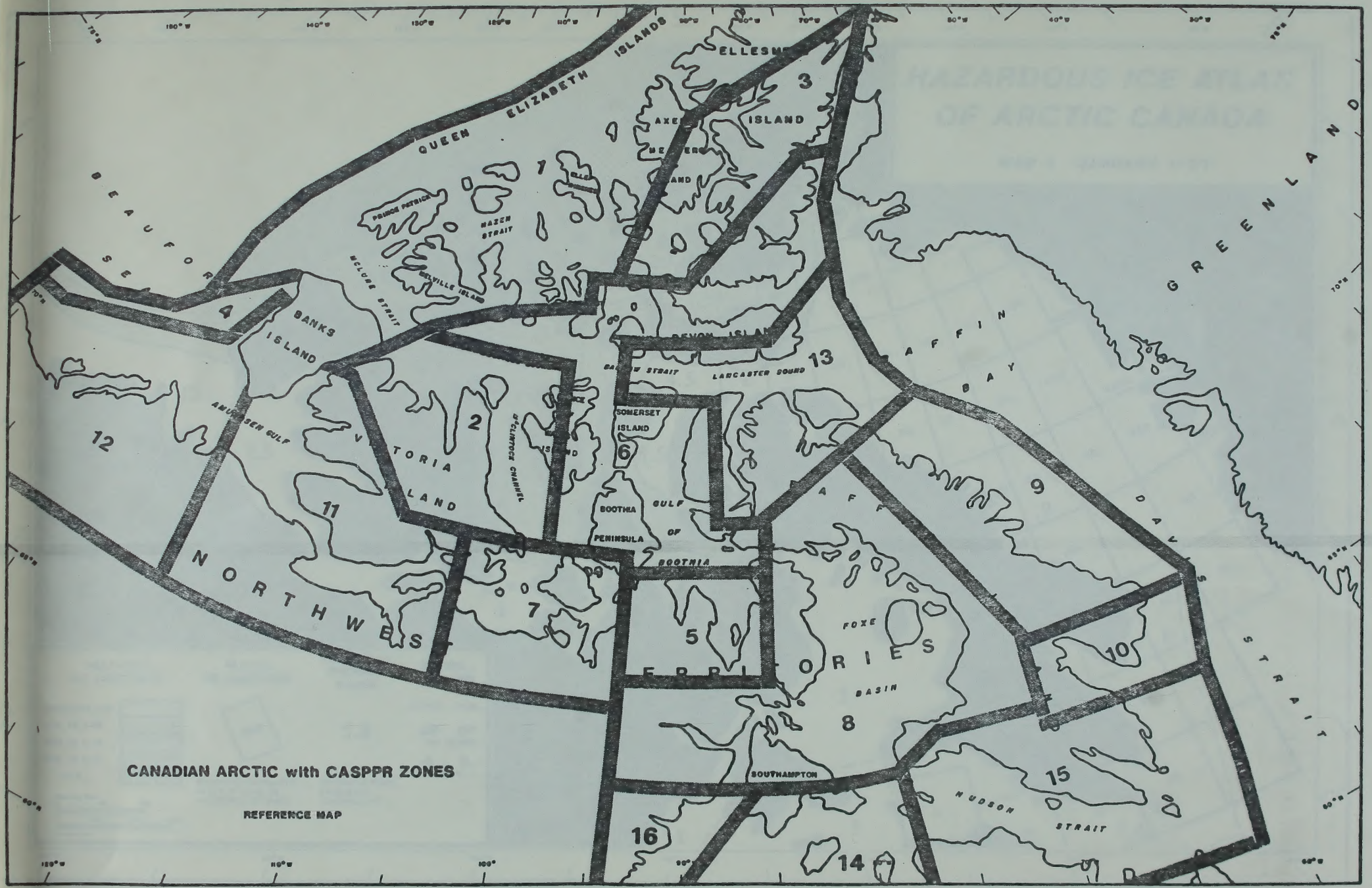
REFERENCES

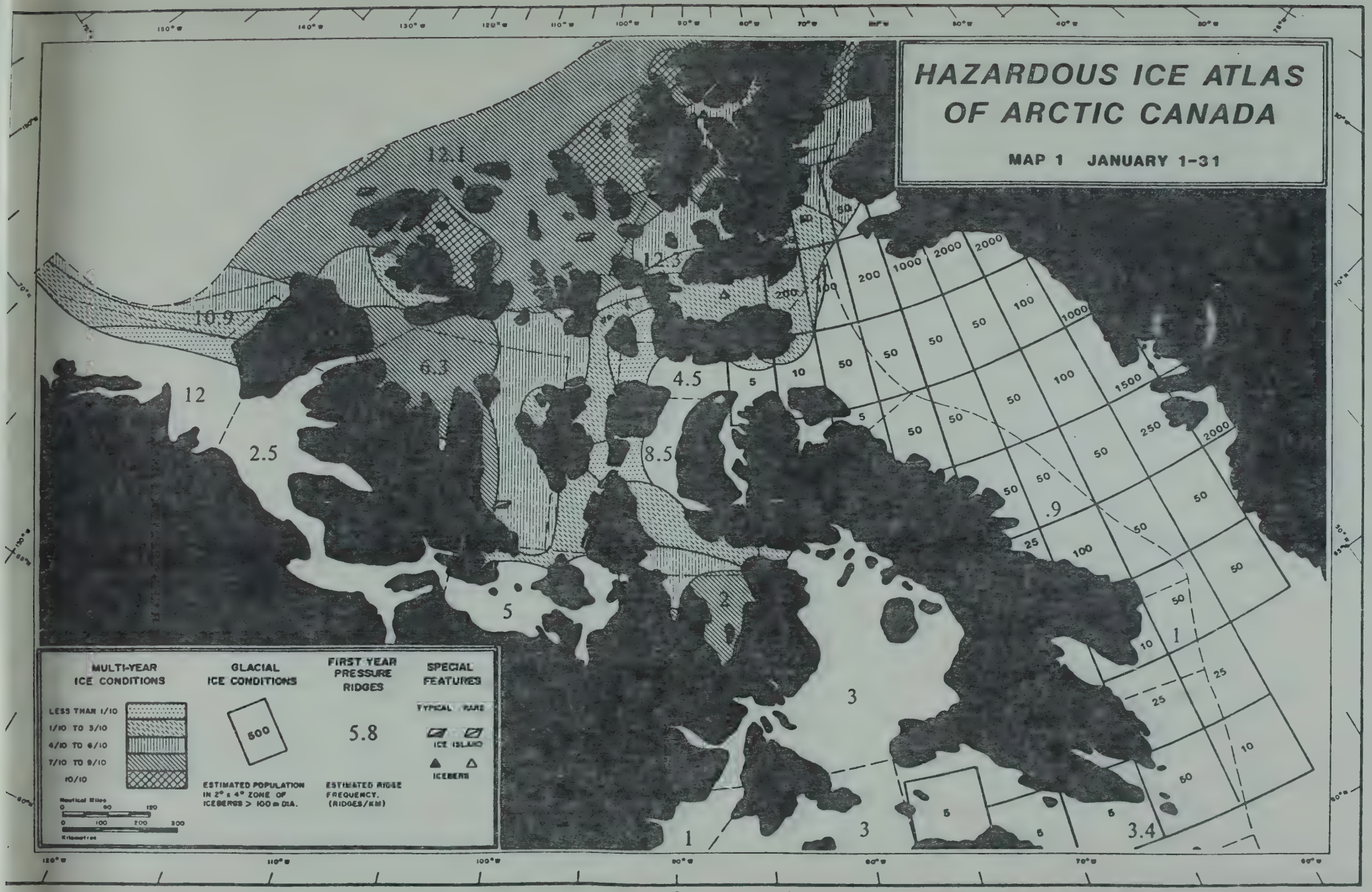
[1] "Studies Supporting Update of the CASPPR Regulations Group I and II" ARCTEC CANADA LIMITED Report No. 586A, to Ship Safety, Canadian Coast Guard, March 1982.

[2] Markham, W.E., "Ice Atlas: Canadian Arctic Waterways", Environment Canada, 1981.

[3] Vandall, P.E., Jr., "Oil Industry's Measurements of the Physical Environment Offshore Labrador" Five years on research in the Labrador coastal and offshore region, 1979.

[4] Lindsay, D.G., "Sea Ice Atlas of Arctic Canada", Department of Energy, Mines and Resources, 1977.


QUEEN ELIZABETH ISLANDS
ELLESMERE ISLAND
BEAUFORT SEA
GREENLAND
BANKS ISLAND
PRINCE PATRICK ISLAND
MELVILLE ISLAND
MCCLURE STRAIT
NANSEN SOUND
AMUNDSEN GULF
VICTORIA ISLAND
PRINCE ALBERT SOUND
DEVON ISLAND
BARROW STRAIT
LANCASTER SOUND
SOMERSET ISLAND
BOOTHIA PENINSULA
GULF OF BOOTHIA
BAFFIN BAY
DAVIS STRAIT
FOXE BASIN
SOUTHAMPTON
HUDSON STRAIT
NORTHWEST TERRITORIES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
CANADIAN ARCTIC with CASPPR ZONES
REFERENCE MAP



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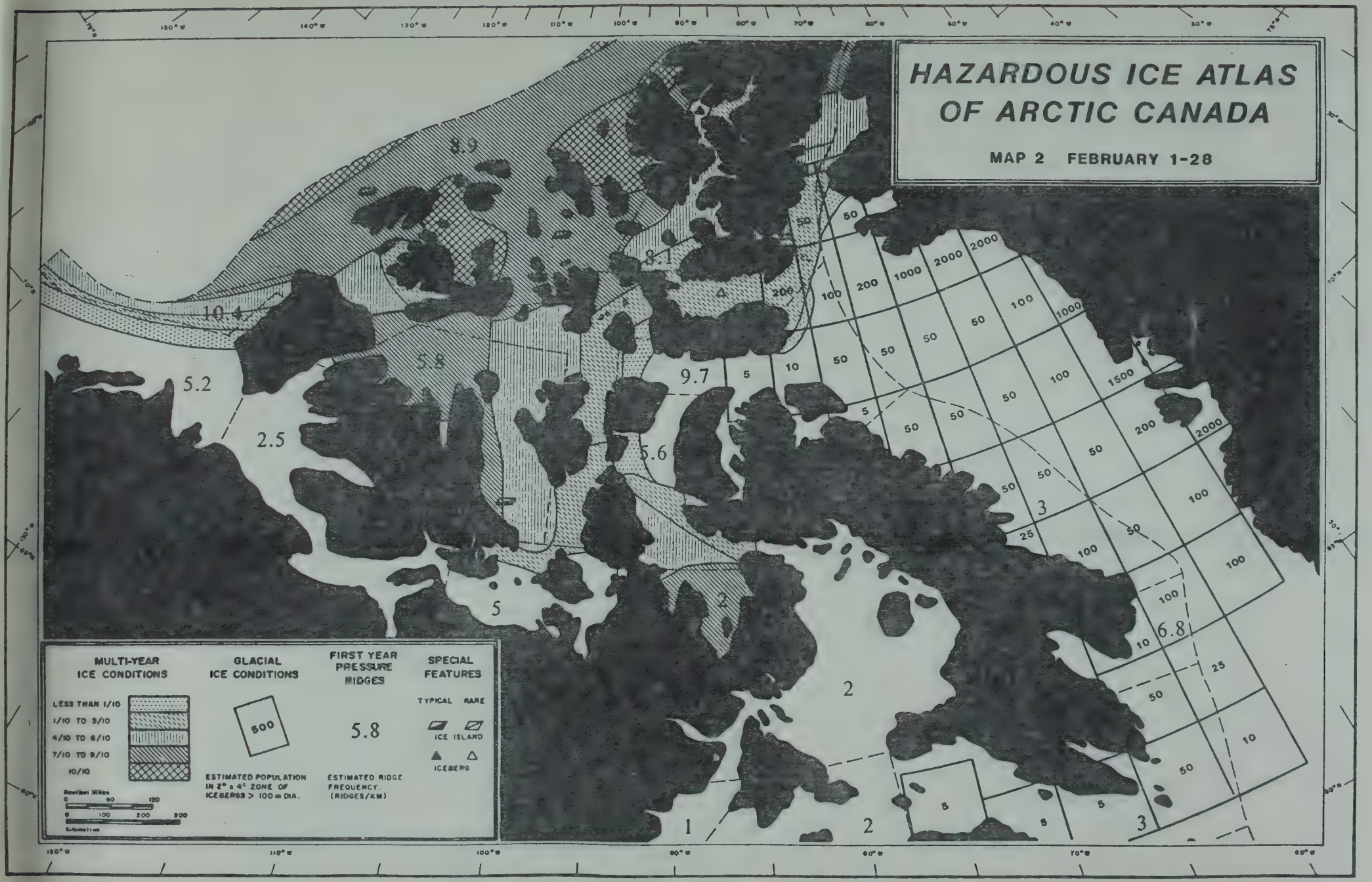
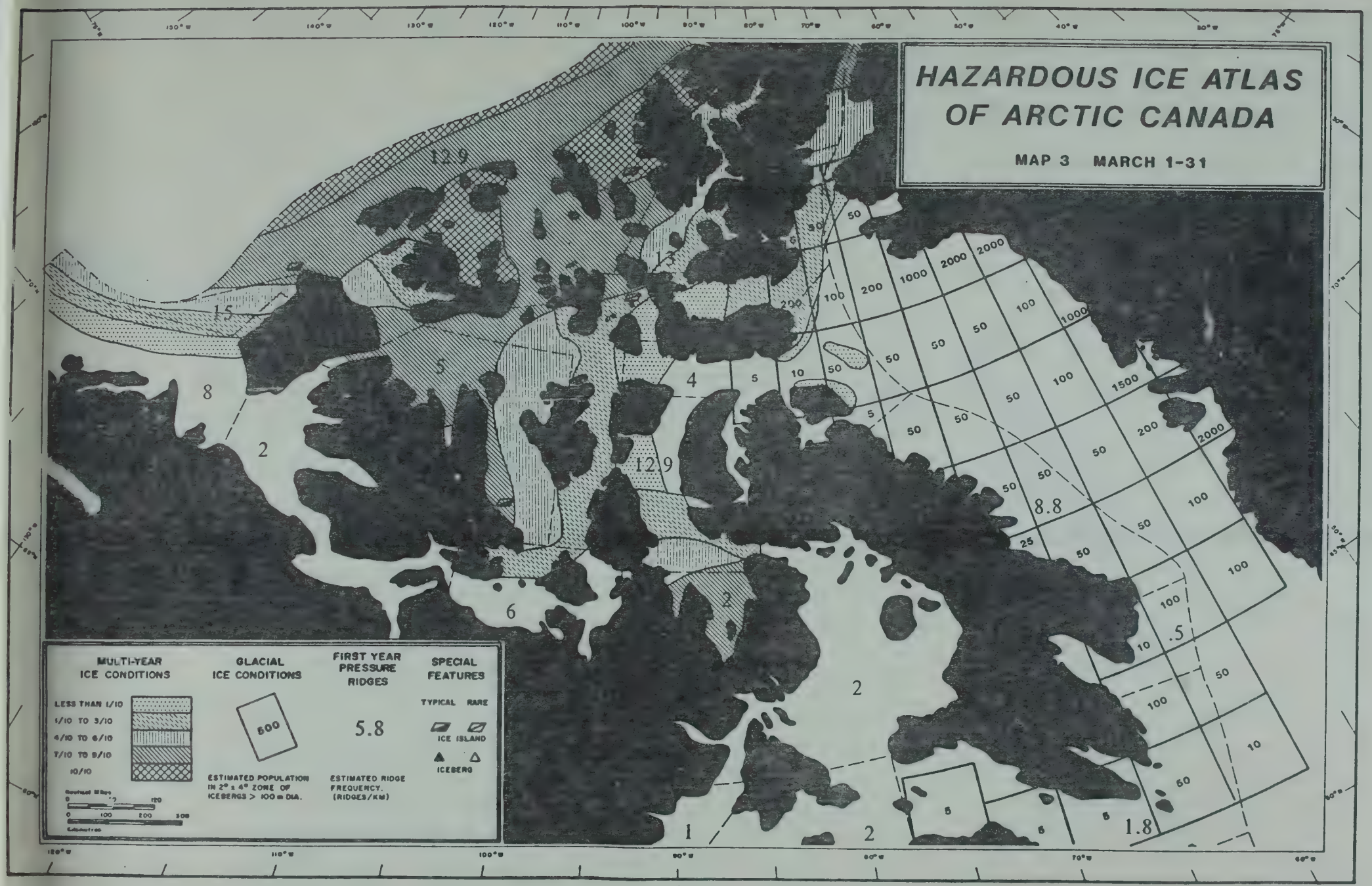
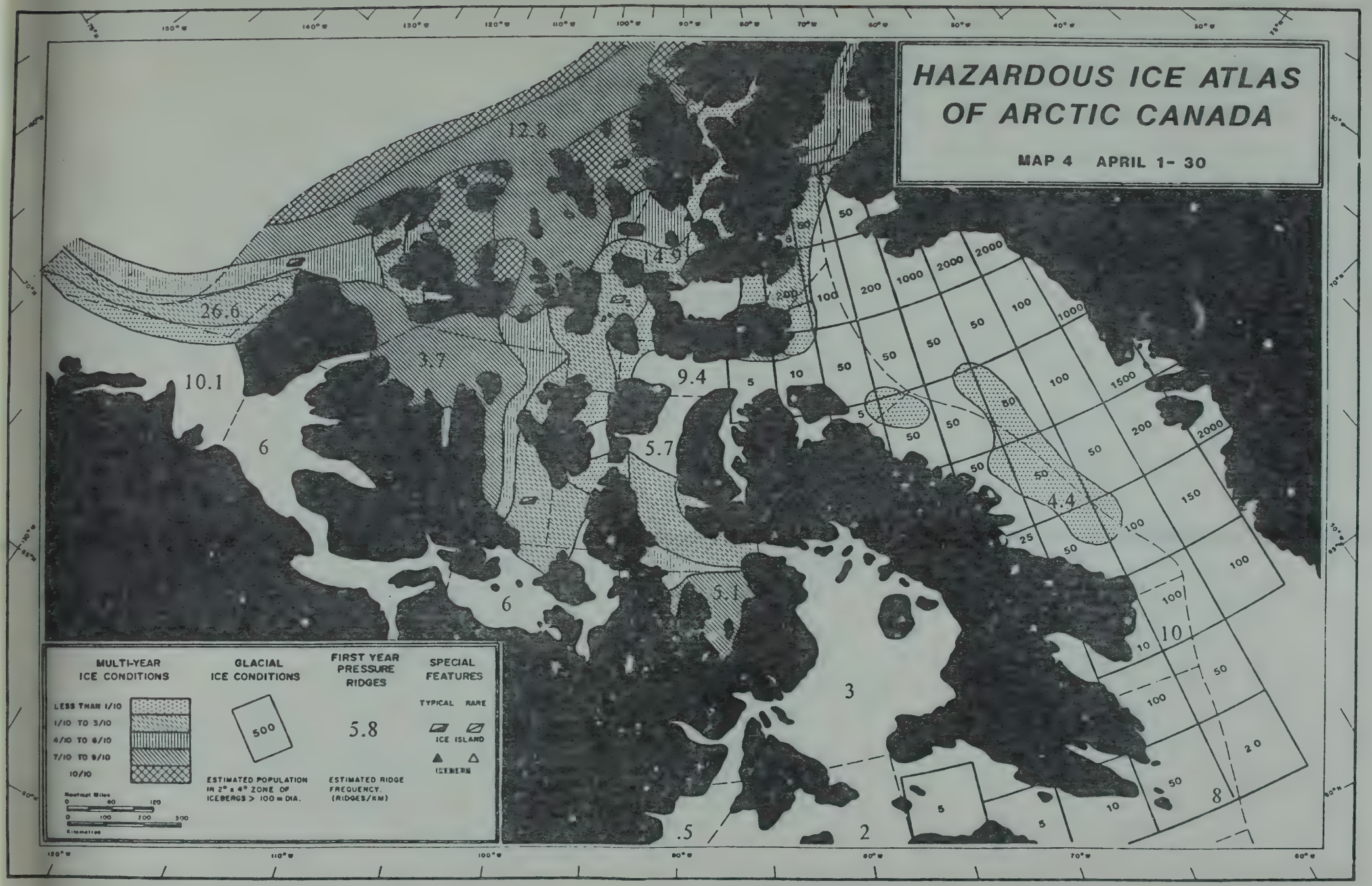
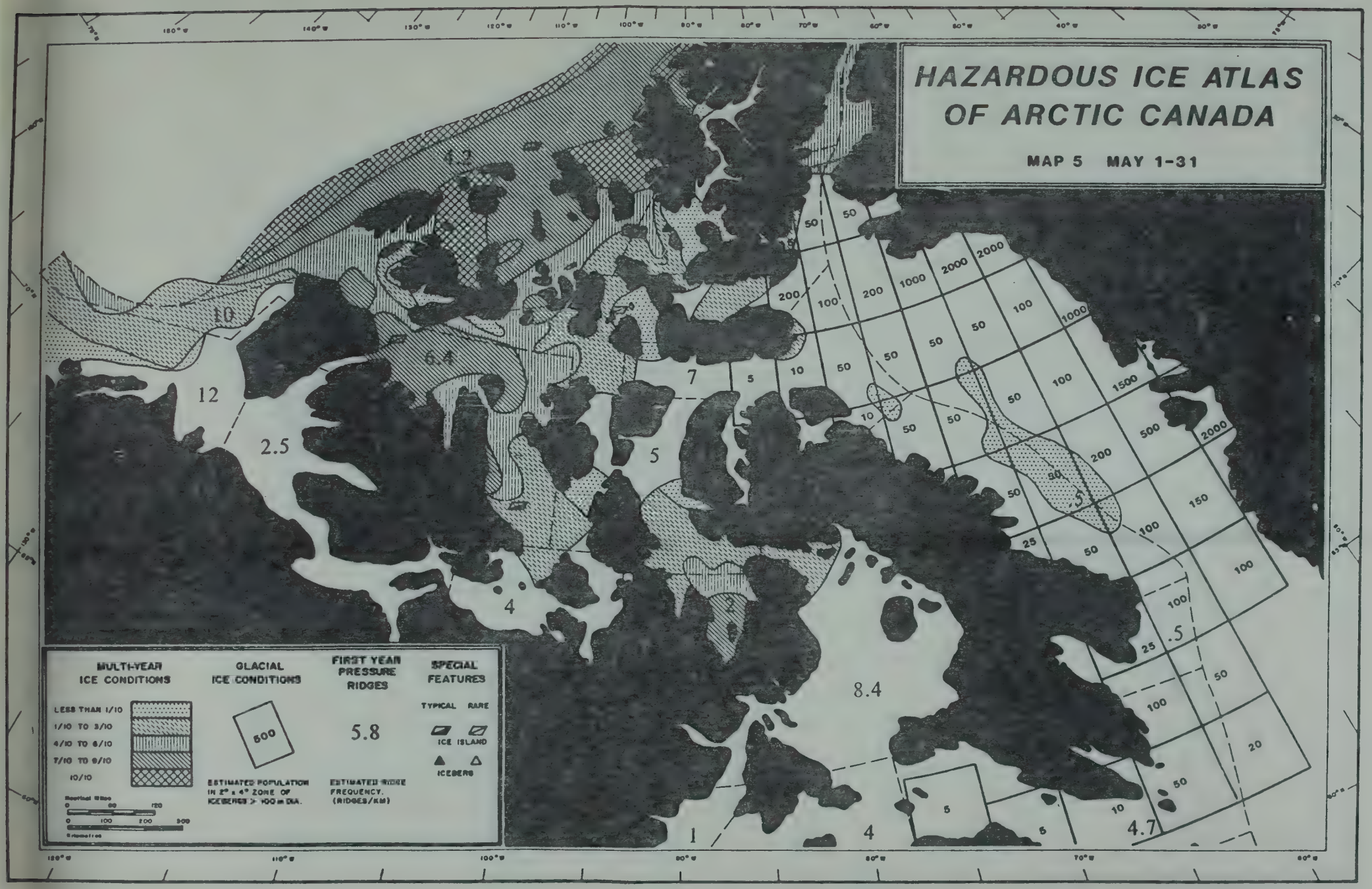
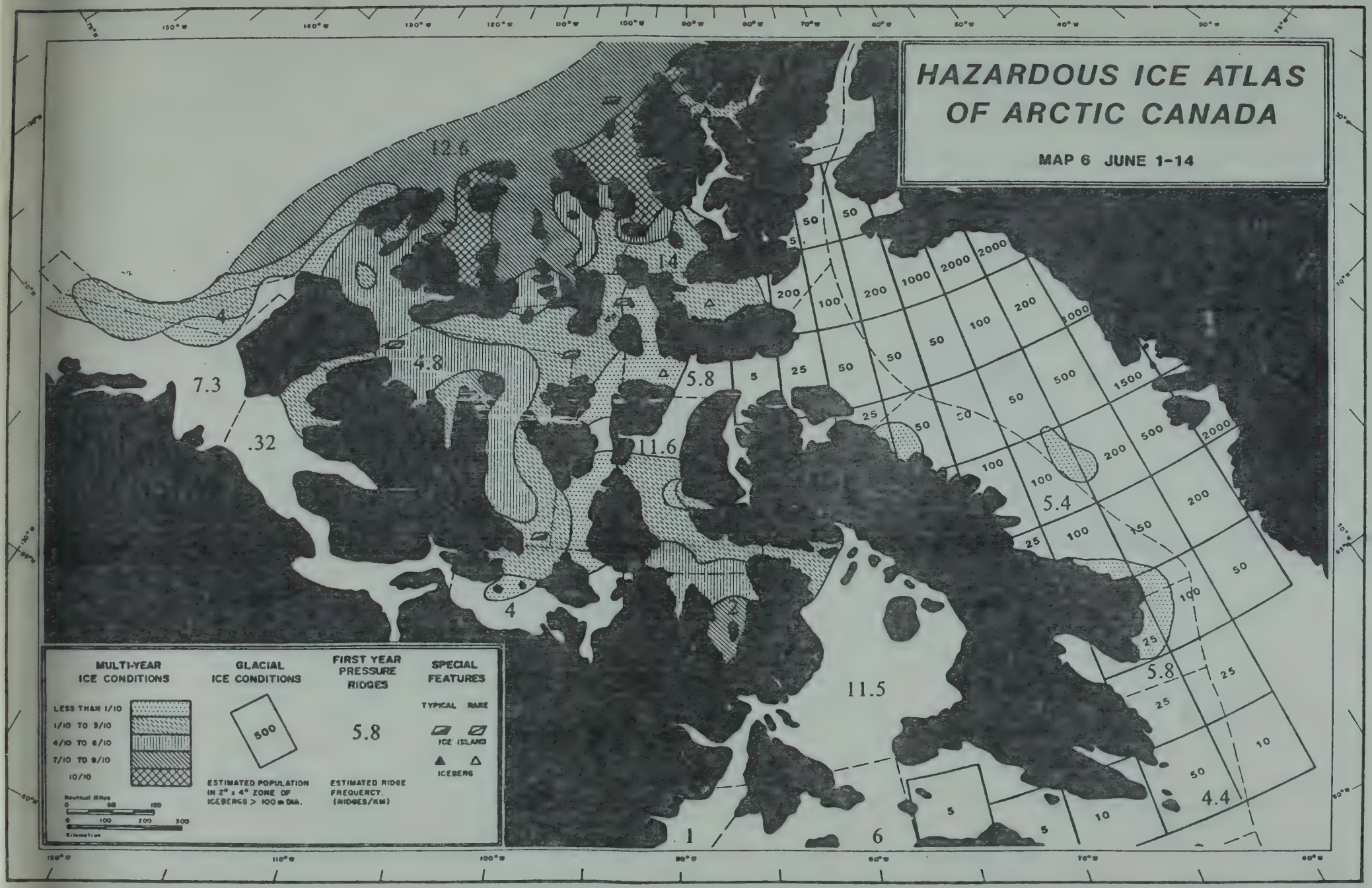

HAZARDOUS ICE ATLAS
OF ARCTIC CANADA
MAP 2 FEBRUARY 1-28
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
500
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY. (RIDGES/KM)
SPECIAL FEATURES
TYPICAL RARE
ICE ISLAND
ICEBERG
8.9
8.1
10.4
5.8
5.2
2.5
9.7
5.6
5
2
6.8
1
3


HAZARDOUS ICE ATLAS
OF ARCTIC CANADA
MAP 3 MARCH 1-31
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
500
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY. (RIDGES/KM)
SPECIAL FEATURES
TYPICAL RARE
ICE ISLAND
ICEBERG
12.9
15
8
2
5
4
10
6
2
1
2
1.8
8.8
.5


HAZARDOUS ICE ATLAS OF ARCTIC CANADA
MAP 4 APRIL 1- 30
12.8
4.9
26.6
3.7
10.1
9.4
5.7
6
6
5.1
4.4
3
2
.5
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
500
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY. (RIDGES/KM)
SPECIAL FEATURES
TYPICAL RARE
ICE ISLAND
ICEBERG


HAZARDOUS ICE ATLAS OF ARCTIC CANADA
MAP 5 MAY 1-31
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
600
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY. (RIDGES/KM)
SPECIAL FEATURES
TYPICAL RARE
ICE ISLAND
ICEBERGS
4.2
10
6.4
12
2.5
7
5
4
2
8.4
1
4
4.7
50
100
200
1000
2000
1500
500
150
25
.5
20



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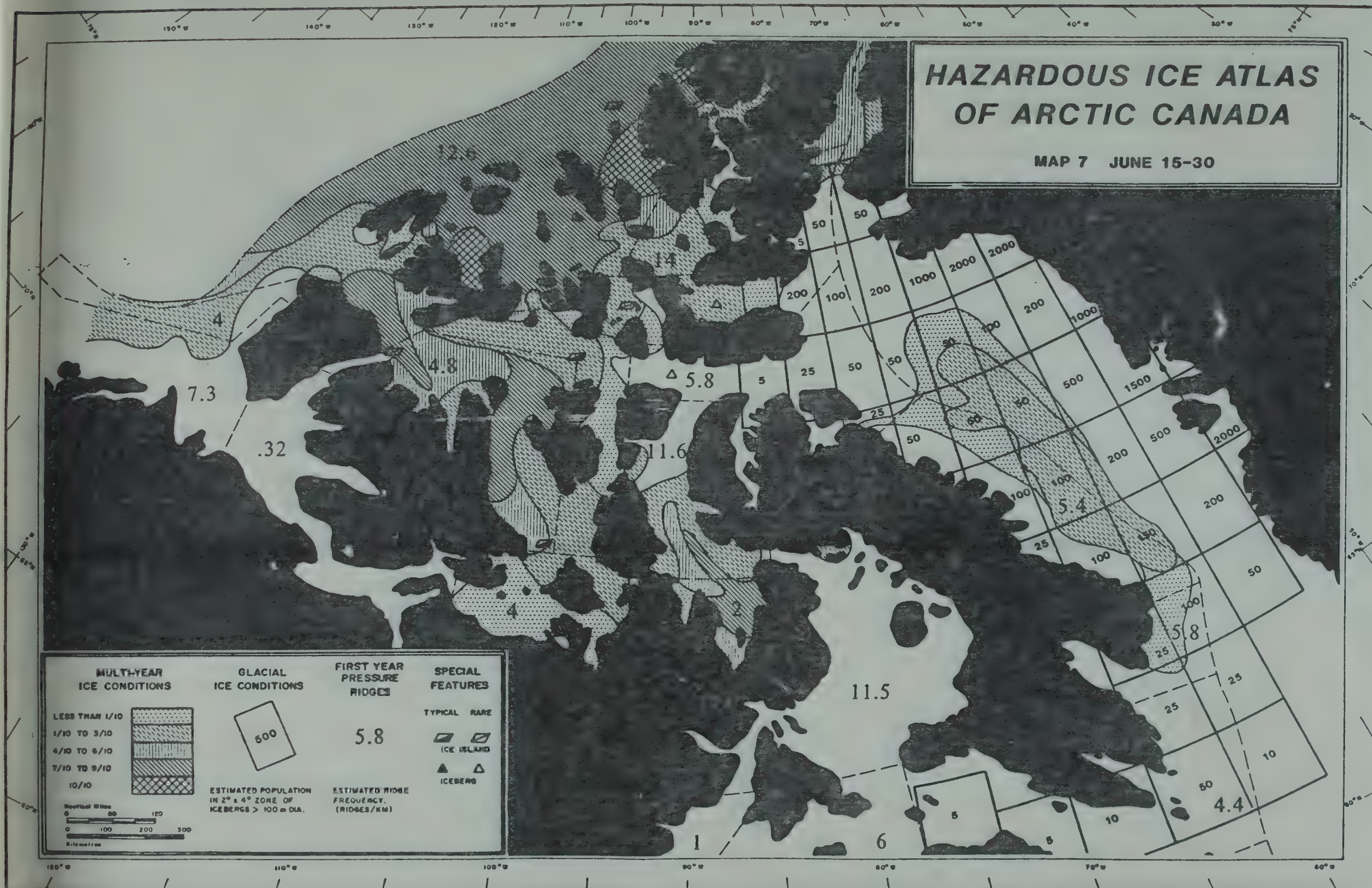
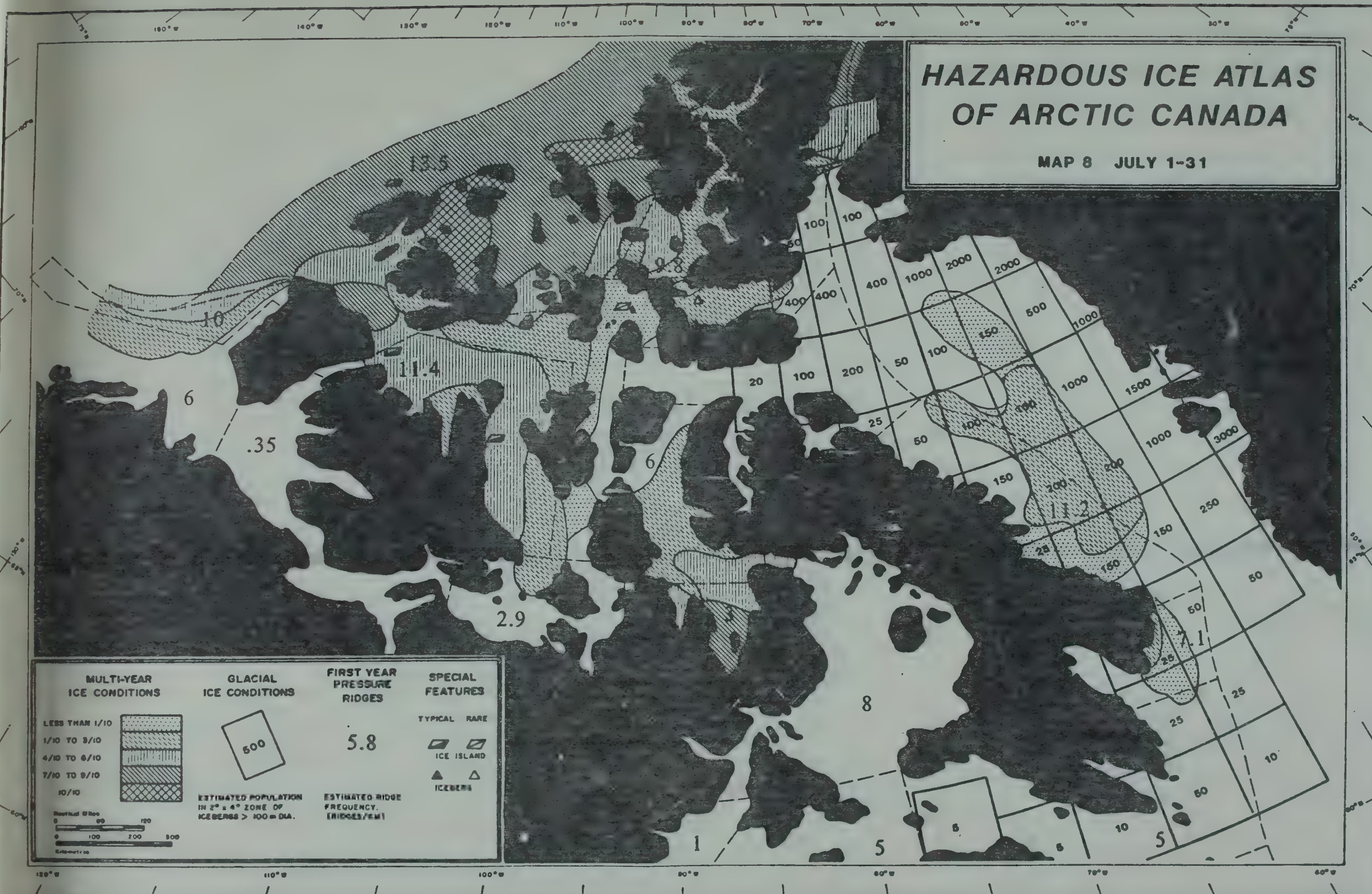

HAZARDOUS ICE ATLAS OF ARCTIC CANADA
MAP 7 JUNE 15-30
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
500
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY (RIDGES/KM)
SPECIAL FEATURES
TYPICAL
RARE
ICE ISLAND
ICEBERG



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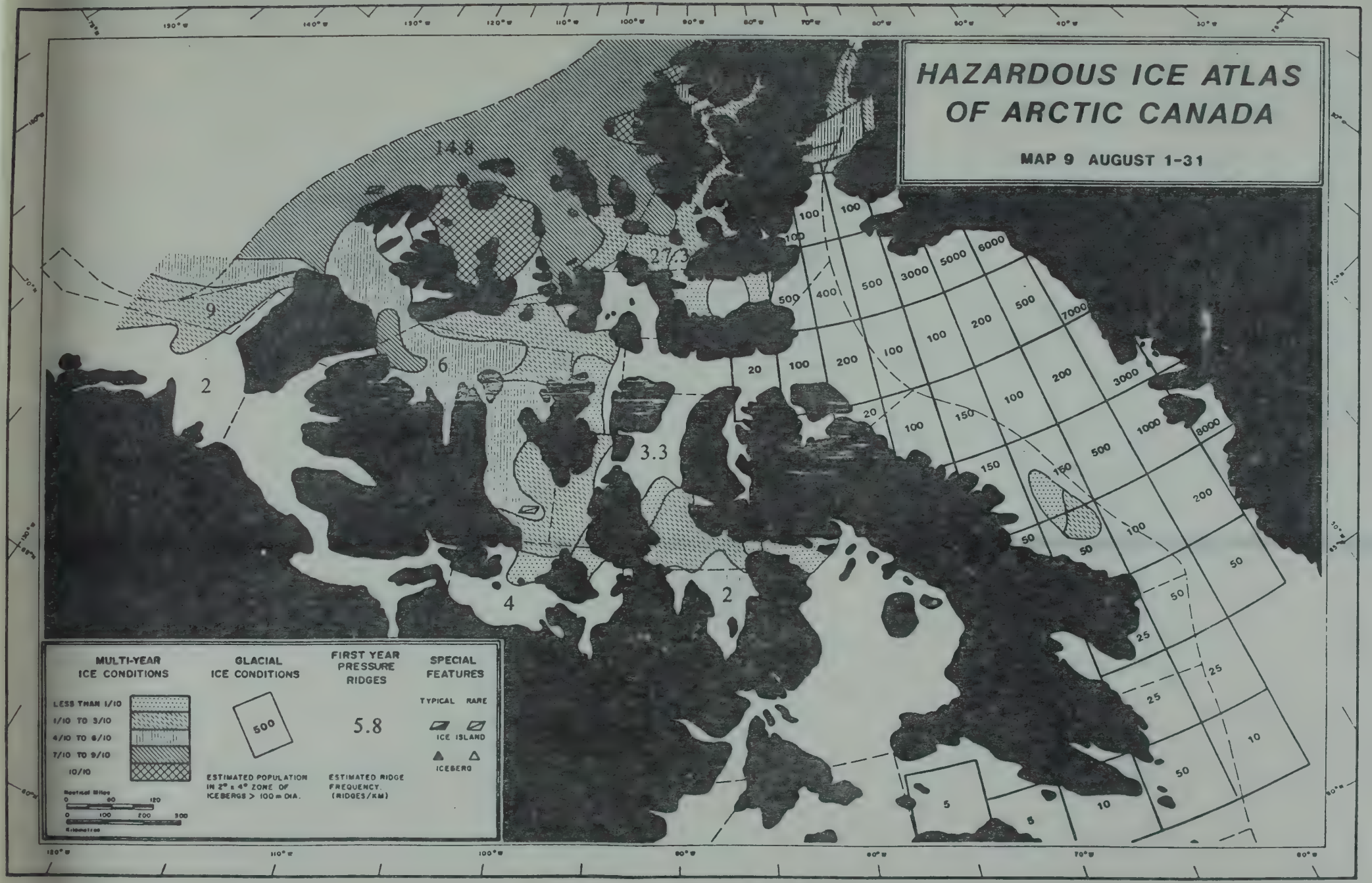
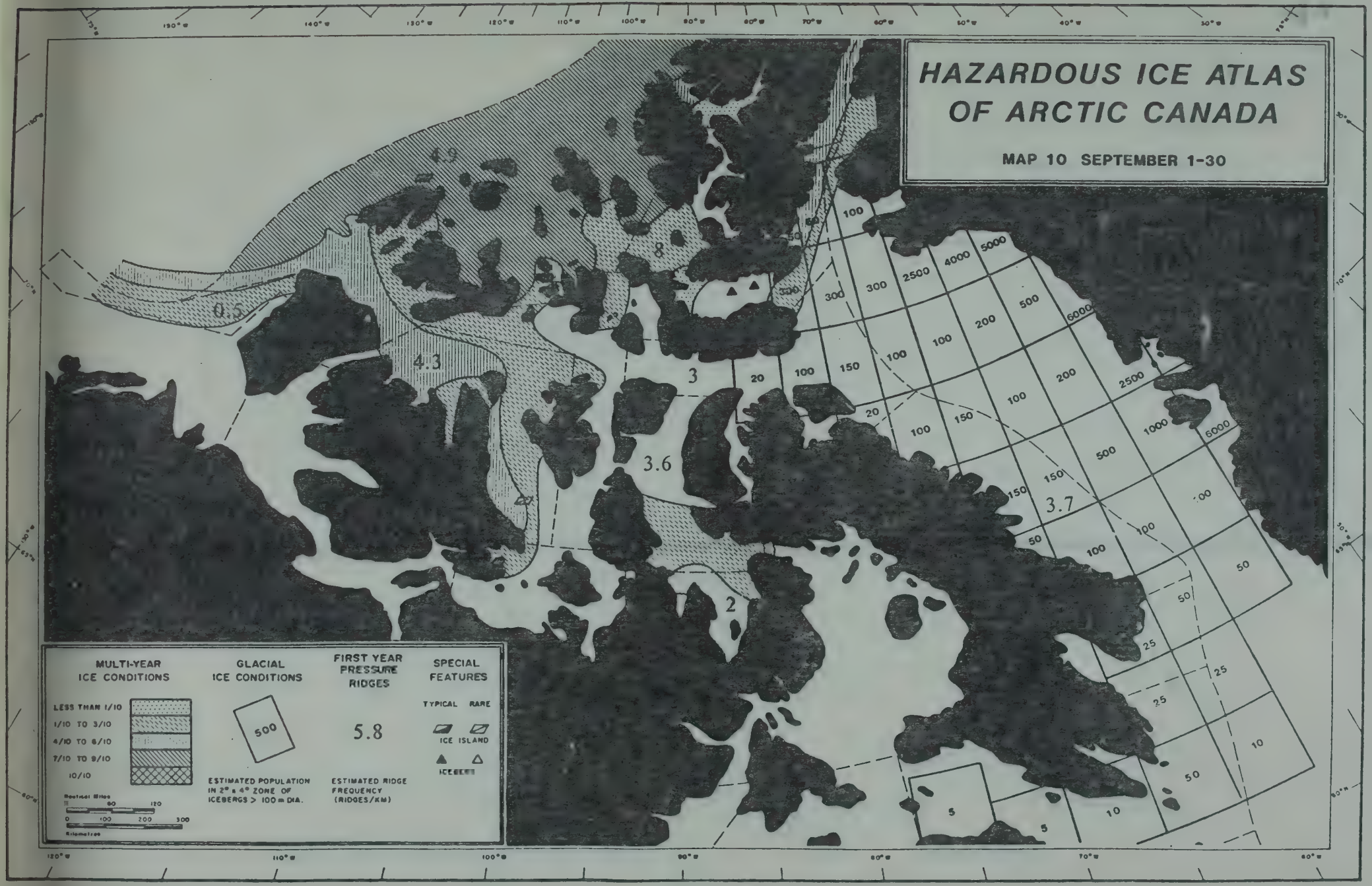

HAZARDOUS ICE ATLAS OF ARCTIC CANADA
MAP 9 AUGUST 1-31
14.8
27.3
9
6
2
3.3
4
2
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
500
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY. (RIDGES/KM)
SPECIAL FEATURES
TYPICAL RARE
ICE ISLAND
ICEBERG
Nautical Miles
Kilometres



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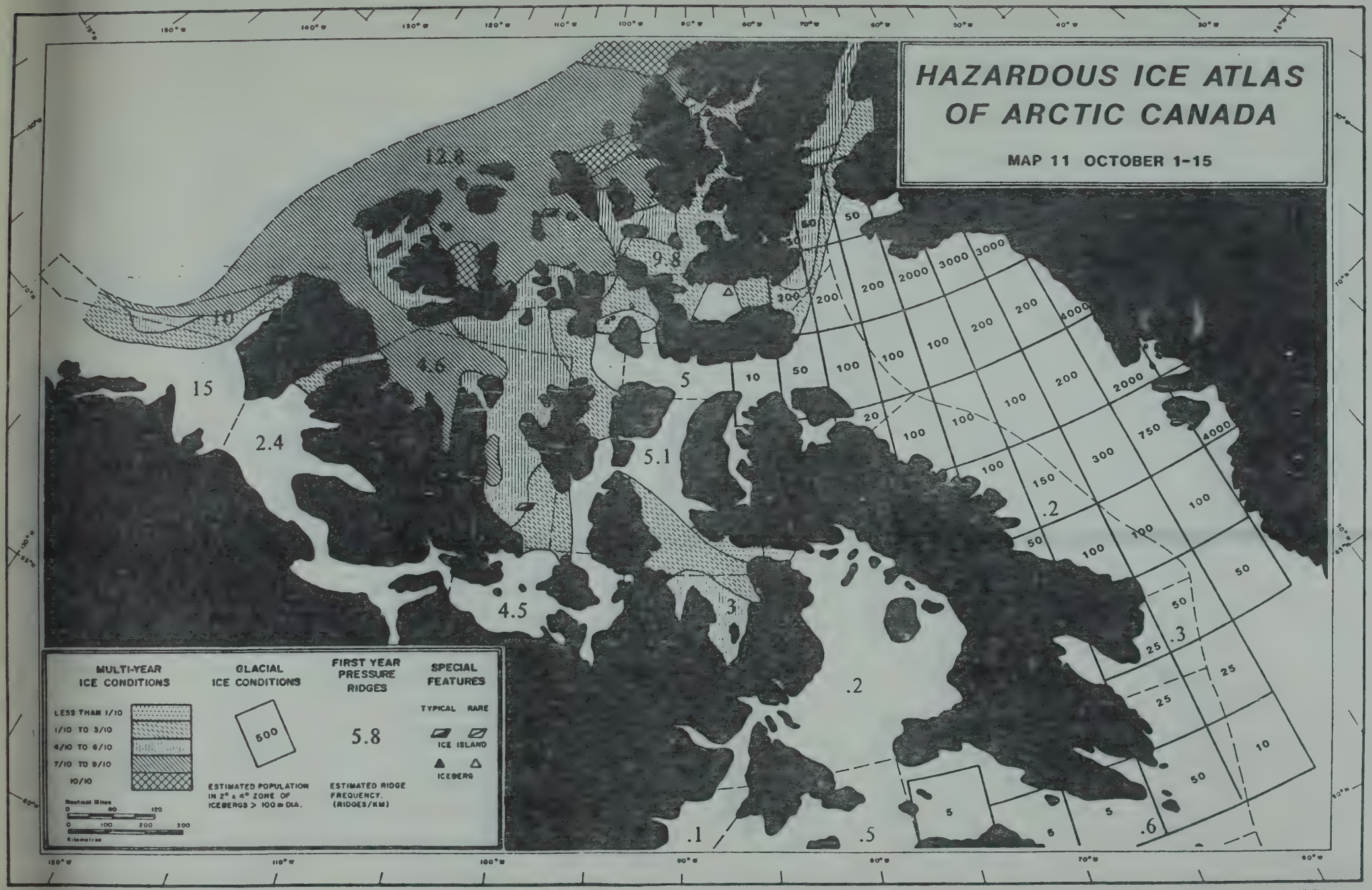
HAZARDOUS ICE ATLAS OF ARCTIC CANADA
MAP 11 OCTOBER 1-15
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
500
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY. (RIDGES/KM)
SPECIAL FEATURES
TYPICAL RARE
ICE ISLAND
ICEBERG
12.6
10
9.8
4.6
15
2.4
5
5.1
4.5
3
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.1
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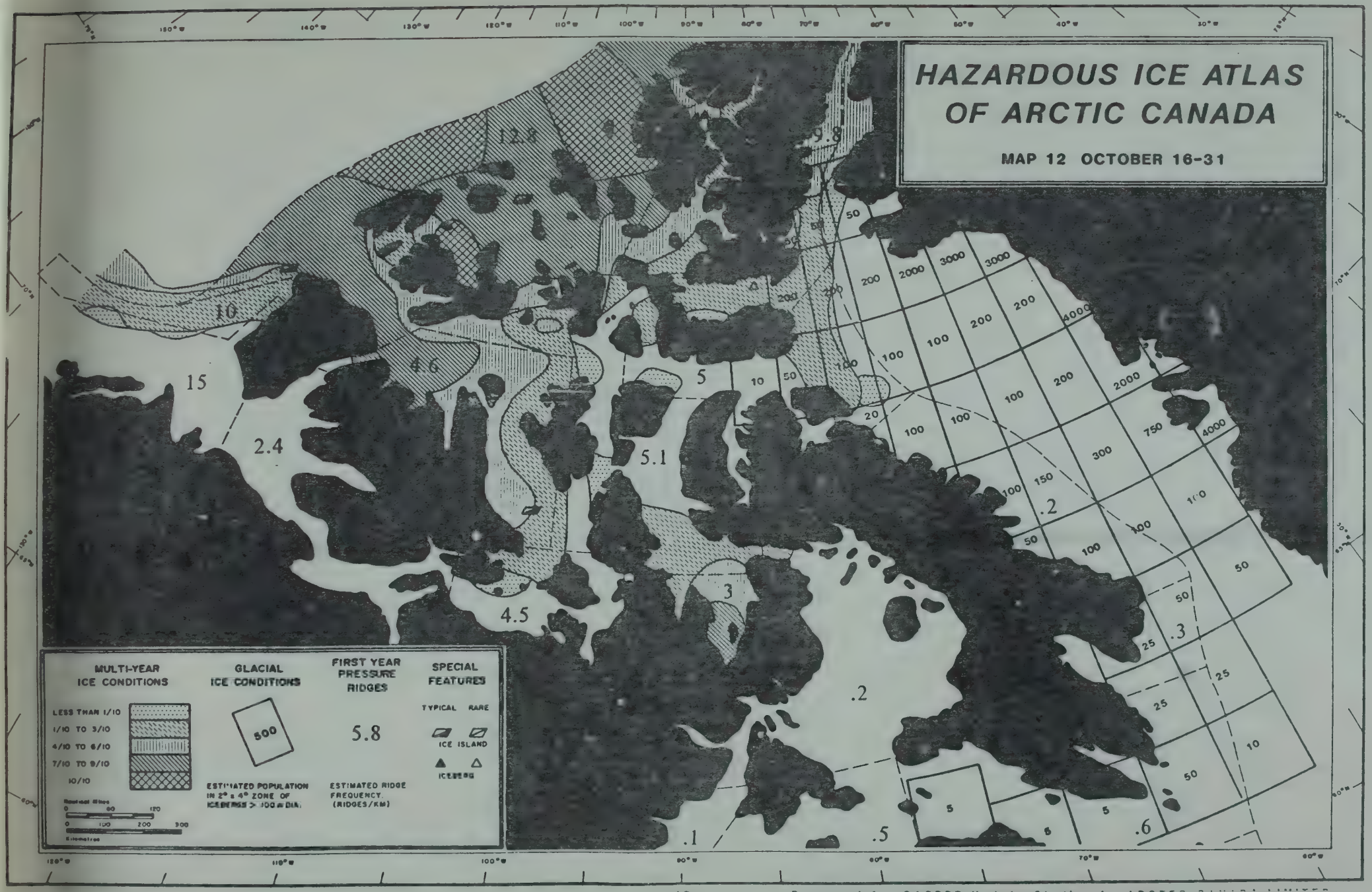
.6


HAZARDOUS ICE ATLAS OF ARCTIC CANADA
MAP 12 OCTOBER 16-31
MULTI-YEAR ICE CONDITIONS
LESS THAN 1/10
1/10 TO 3/10
4/10 TO 6/10
7/10 TO 9/10
10/10
GLACIAL ICE CONDITIONS
500
ESTIMATED POPULATION IN 2° x 4° ZONE OF ICEBERGS > 100 m DIA.
FIRST YEAR PRESSURE RIDGES
5.8
ESTIMATED RIDGE FREQUENCY (RIDGES/KM)
SPECIAL FEATURES
TYPICAL RARE
ICE ISLAND
ICEBERG
12.8
9.8
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15
4.6
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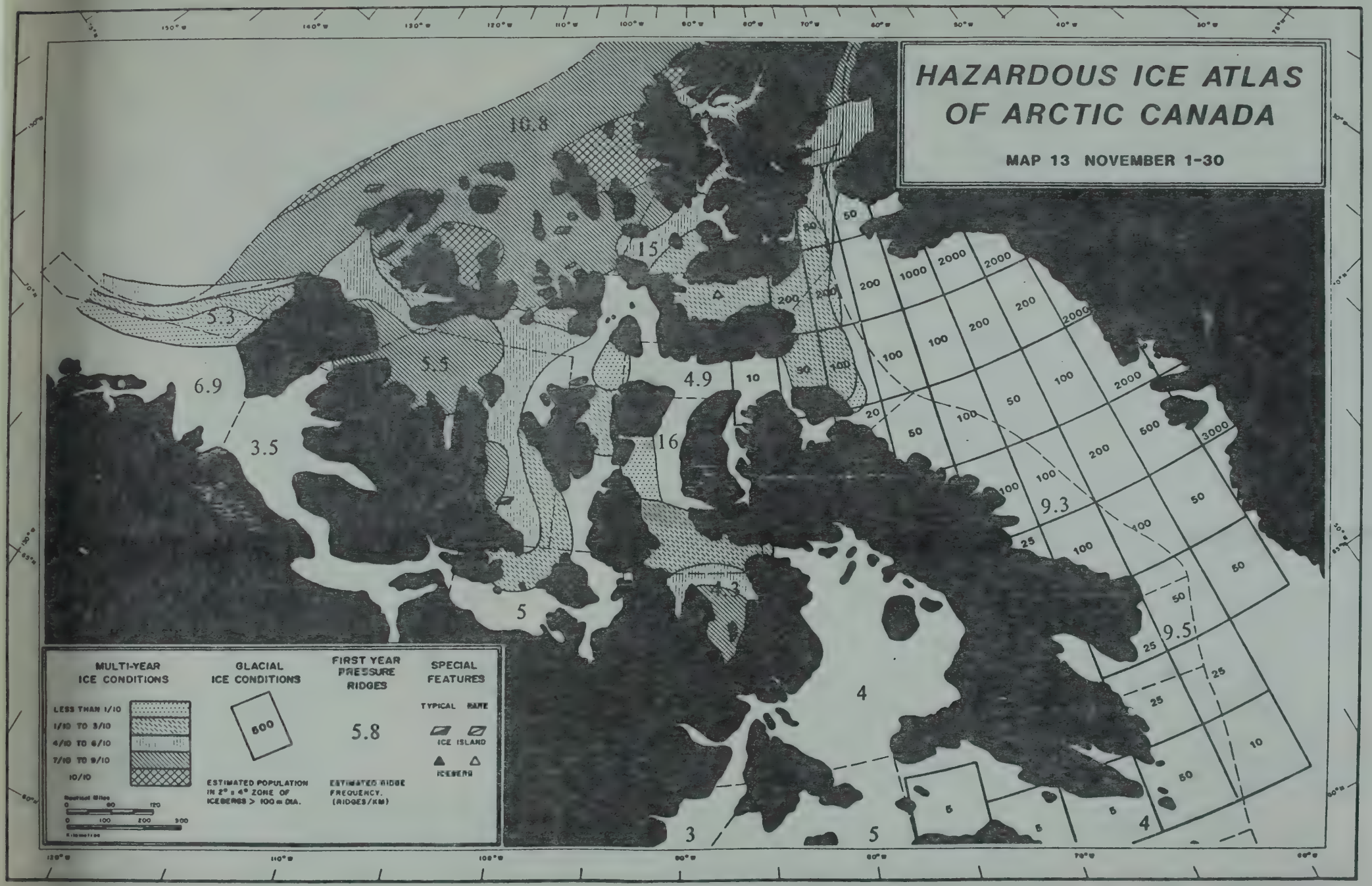

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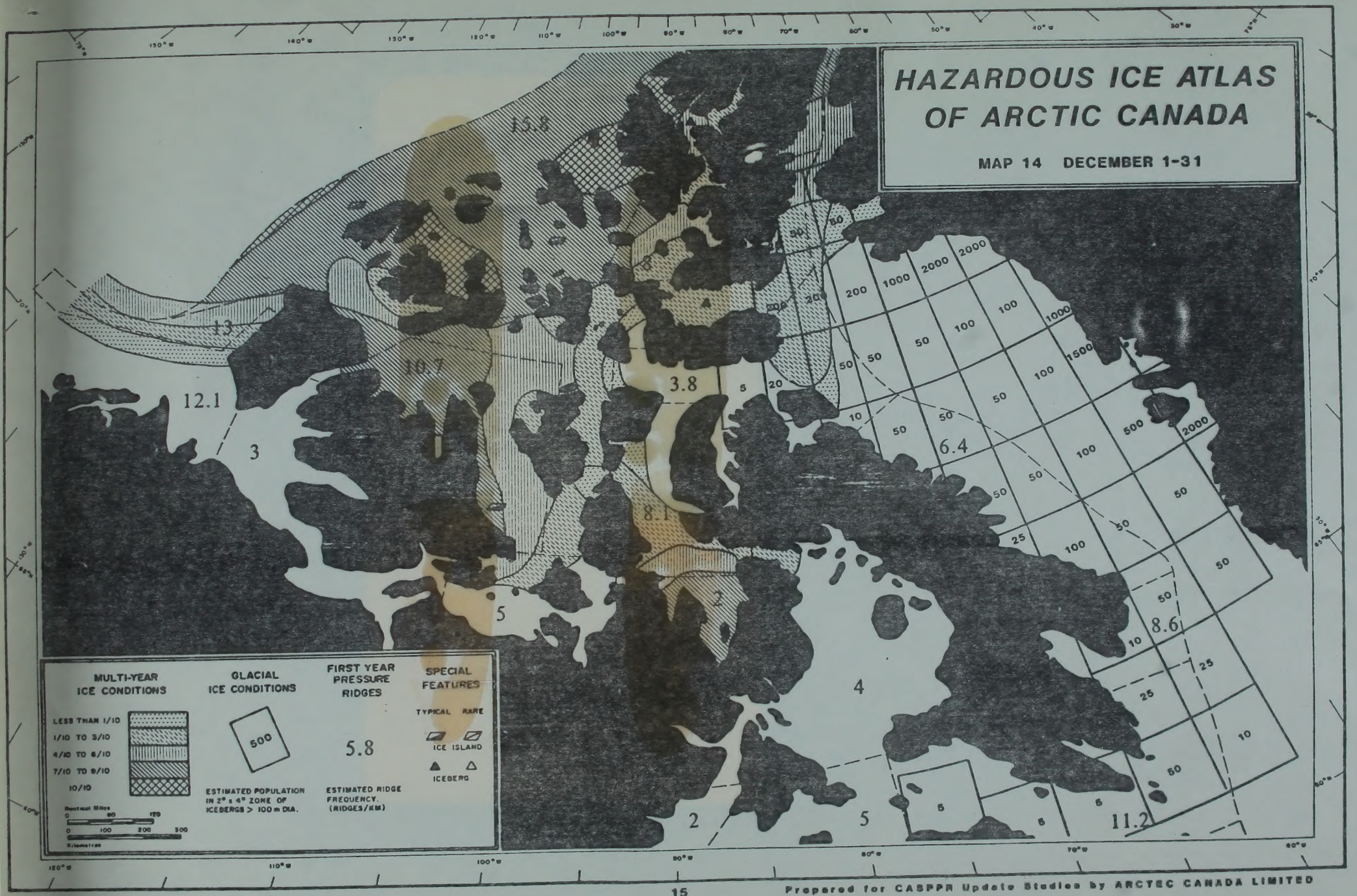

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